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Smart grid electricity system planning and climate disruptions: A review of climate and energy discourse post-Superstorm Sandy

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ABSTRACT

Superstorm Sandy hit the northeastern United States in October 2012, knocking out power to 10 million people and highlighting energy and critical infrastructure system vulnerabilities in the face of a changing climate. The increased frequency and intensity of such disruptive events is shifting priorities in electricity system planning around the world, including how multiple stakeholders consider linkages between climate vulnerability and energy. This research links smart grid development with adaptation to changing climates and explores how different stakeholders grapple with system vulnerabilities and climate disruptions. To illustrate this, the in-depth case study assesses post-Sandy discourse to compare how electricity sector stakeholder groups in New York, Massachusetts and Vermont associate energy, smart grid, and climate change. To explore how different energy system stakeholders frame the impacts of Superstorm Sandy on energy system planning, we conducted 22 focus groups with a broad range of organizations representing diverse aspects of the electricity system including utilities, regulatory authorities, research and development agencies, regional transmission organizations, academic research institutions, consumer advocacy and environmental organizations across the three states. We used these data to examine post-Sandy discourse about climate mitigation and climate adaptation, routine system management, and the potential value of "smart grid" for future energy system planning. We found that both New York and Massachusetts stakeholders focused more on climate adaptation than climate mitigation, while stakeholders in Vermont focused more on mitigation. In all three states stakeholder discussions of adaptation focused most heavily on system resilience and reliability, whereas discussions of mitigation focused on demand-side management and demand response followed by alternative energy strategies. These results suggest that extreme weather and climate disruptions will differentially shape discourse around smart grid and energy system change and shift the focus among energy system stakeholders on climate adaptation compared to climate mitigation. This research demonstrates variation between political jurisdictions (states) and energy system stakeholders in energy system planning in the face of new challenges related to an uncertain and rapidly changing world.

1. Introduction

Superstorm Sandy has been characterized as "the storm of a lifetime—a massive, freakish confluence of a tropical hurricane and a winter, extratropical vortex" [1], pg. 15). Starting as a tropical storm in the southern Caribbean, Sandy travelled north and made landfall as a cyclone in Atlantic City, New Jersey. The storm caused power outages and fuel shortages for over 10 million Americans and resulted in an estimated $60 billion in damages [1,2]. From October 29th through the 31st 2012, Sandy wreaked havoc along the Atlantic coast, with high winds coupled with a high tide leading to a massive storm surge and widespread flooding and damage. Sandy caused monumental devastation and became a focusing event for discussions of climate change, infrastructure vulnerabilities, and the need for upgrades to electricity infrastructure.

Focusing events are widely recognized as specific events that become vehicles for public and political discussion on salient topics [3–5]. Birkland [4] defined a focusing event as "an event that is sudden; relatively uncommon; can be reasonably defined as harmful or revealing the possibility of potentially greater future harms; has harms that are concentrated in a particular geographical area or community of interest; and that is known to policy makers and the public simulta-

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neously" (p. 54). Such phenomena can be environmental in nature, such as extreme weather events, or social, such as policy implementation [5].

Climate change and increased weather variability around the world underscores the interlinked nature of critical infrastructure vulnerabilities [6]. Superstorm Sandy was a focusing event that highlighted the threat of extreme weather events exacerbated by climate change. Among the many different vulnerabilities associated with this event, including food, water, housing, and transportation; energy system vulnerability was particularly prominent in many regions of New York and New Jersey following the storm. Widespread power outages and fuel shortages occurring in this region focused attention on connections between climate change and energy systems and their impacts on critical infrastructures in the United States. Not only was the extreme event framed as representing a pattern of climate change that justified stronger climate mitigation efforts, but the storm also provided new incentives for considering climate adaptation measures by highlighting the vulnerability of energy systems [7].

Recognizing the complexity associated with integrating both climate adaptation and climate mitigation into electricity system planning and smart grid investment around the world [8], this paper develops an in-depth case study to explore post-Superstorm Sandy discourse about climate change among electricity system stakeholders to compare how climate and energy are being discursively linked in electricity system planning and smart grid development. We conducted focus groups with energy stakeholders (utilities, environmental groups, regulators, and others) in New York, Massachusetts, and Vermont. The goal of our comparative analysis was to identify discursive patterns related to climate mitigation and adaptation in conversations with electricity stakeholders who are directly involved in energy system planning and operation and who had occupational and/or personal experience with the focusing event provided by Superstorm Sandy. We selected three states that were differently impacted by Superstorm Sandy to enable comparative assessment of conversations about energy policy and planning that emerged following this focusing event. These conversations suggest a broad array of socio-political dimensions that need to be considered by those who are interested in promoting a more sustainable energy system. We first contextualize the study within a broader literature review, explain the methods, then present and discuss the results of our three-state analysis. This is followed by conclusions and reflections on the value of this study to understand how focusing events like Sandy allow for deeper exploration of different and somewhat divergent responses to changing energy system risks and climate adaptation of critical infrastructures.

2. Literature review

While the electricity grid is only one of many vulnerable infrastructure systems facing major challenges with more frequent extreme events related to climate change, it is particularly important because society has become increasingly dependent on electricity for basic functions such as transportation, communication, and financial transactions [9]. Recognition of system-wide vulnerabilities in electricity generation, transmission, and distribution has contributed to a growing literature addressing energy system planning, changing operations and "smart grid" investments to ensure the power system remains resilient, reliable, and affordable while also transitioning to a low-carbon energy system [10–13]. Smart grid is not a specific technology but is rather a term that includes new technologies as well as other potential upgrades and improvements to electricity grids. This umbrella term is politically attractive, seemingly benign, and somewhat ambiguous [9]. While it includes a plethora of diverse technical and social changes to the electricity system, a common theme across different definitions of smart grid is the integration of information technology into electricity system management. As such, it includes a variety of interlinked technologies including advanced meters and sensors as well as other technological configurations that contribute to climate change mitigation by enabling the inclusion of more renewable electricity on the grid and promoting system efficiency [8,14–20]. These socio-technical configurations also contribute to climate change adaptation by increasing system resilience in the face of both severe weather events such as Superstorm Sandy and malicious attacks on the grid [21–23]. Electricity system changes incorporated under the smart grid umbrella include technological shifts to enhance resiliency in anticipation and in preparation for more disruptive weather events; we consider these changes to be climate adaptation measures [8]. Also incorporated under the smart grid umbrella are electricity system changes that facilitate higher penetration of low-carbon energy technologies, reduce environmental impacts, enhance system efficiency and support increased demand-side management; we consider these changes to be climate mitigation measures. [8,24]. Although overlap and synergistic opportunities exist between climate adaptation and climate mitigation [25], divergent perspectives on which electricity system upgrades and what smart grid investments and changes are most critical are emerging among those who prioritize adaptation versus those who prioritize mitigation [8,26].

3. Post-Sandy discourse analysis: methods

We conducted 22 focus groups with a variety of energy system stakeholders in three states (7 in New York, 8 in Massachusetts, and 7 in Vermont) during the year after Superstorm Sandy (November 2012-November 2013) to examine the impacts of the storm on energy system discourse involving smart grid technologies. We chose focus groups as our data collection method because they offer exposure to conversations highlighting the trending information, knowledge, language, and experiences of a specific set of topics from targeted constituents [27]. Additionally, from focus groups salient themes can be identified and later categorized to allow for insights and articulation of particular sets of topics or ideas [27]. The conversational nature of a focus group also encourages participants to build upon and otherwise interact with accounts offered by other participants [28].

A comparative approach of three states with different proximities to the center of the storm created a gradient of storm damage and disruption (though we acknowledge that impacts within the states were not uniform). Because the level of damage decreased as the storm proceeded up the coast, New York was the state most severely impacted by Sandy, suffering extensive property destruction, power outages, and gas main breaks from high winds, flooding, and storm surge. Like New York, Massachusetts also experienced power outages as well as road closures and building damage, mainly due to high winds and flooding. The disruption, however, was not as extensive as in New York. Vermont, the state impacted the least, suffered mostly from high winds and heavy rainfall, causing downed power lines and road closures. These three states were also selected because they represent the broad variety of social systems that characterize the Northeast region of the United States, including cultural, economic, and political differences. The three states also share important regional electricity system planning characteristics.

Each focus group included 3–8 representatives of a single organization and lasted between 60 and 90 min during which participants were prompted to discuss their perspectives on smart grid, climate change, and electricity system change. Organizations represented in these focus groups were selected based on their involvement in electricity system decision-making. Although these organizations tended to be physically located in different parts of the states, most had state-wide responsibilities, thus providing a "state-wide" perspective on the impacts of the storm. We categorized participating organizations into two groups: (1) energy system operation experts (i.e., organizations that are directly involved with and responsible for daily operation of the electricity system) and (2) energy system actors (i.e., organizations that have broader temporal and spatial influence on electricity systems but are not directly involved in day-to-day operation). The first category encompasses utilities,

Table 1
Energy system stakeholder categories and descriptions.

Stakeholder Categories	Stakeholders	Stakeholder Role in Energy Transmission
Energy System Operation Experts	Investor Owned Utilities	For-profit enterprises engaged in production and/or distribution of electricity for use by the public and obligated to shareholders. Shareholders do have to be serviced by the utility.
	Electric Cooperatives/Municipal Utilities	Not-for-profit enterprises engaged in production and/or distribution of electricity. Shareholders are only within the service area of the cooperative or municipality.
	Regional Transmission Organizations	Independent federally regulated and established to coordinate regional transmission to ensure the safety and reliability of the regional electric system. Also known as an Independent System Operator (ISO).
	Program Implementation Organizations	Public benefit corporations responsible for providing technical expertise, information and analysis as well as offering innovative energy programs to the public.
Energy System Actors	State-Level Regulatory Authorities	Responsible for the oversight of investor-owned electric power utilities through regulatory creation and enforcement. Monitors service quality, infrastructure planning, and ensures ratepayers rights.
	Researchers	Partakes in research and development of electricity infrastructure technology, policy and regulatory analysis, and advises regulatory bodies and other interested parties.
	Environmental Advocacy Non-Profits	Partakes in legislative energy and climate action, policy research, energy planning and usage advocacy.
	Consumer Advocacy Non-Profits	Partakes in energy related legislative advocacy on behalf of consumers including fair rates advocacy, policy research, and programmatic solutions to enhanced energy usage.

Table 2
Adaptation and mitigation subcategories and descriptions.

Categories	Subcategories	Description
Adaptation	Reliability	Provision of continuous, quality electricity adequate to meet customer demand without interruption.
	Resiliency	Ability of electricity system to adapt to changing conditions, absorb shocks, avoid cascading failure, and recover rapidly from disruption.
	Restoration	Reestablishment of electrical power service to normal conditions after a system emergency.
Mitigation	Alternative Energy Strategies	Use of legal, technological, and economic tools to support renewable and alternative electricity generation, storage, and distribution.
	Decreased Emissions and Environmental Benefit	Reduction of electricity system environmental impact through pollution prevention and decreased greenhouse gas emissions.
	Demand Side Management and Demand Response	Management and reduction of peak load through load shifting, efficiency, and conservation. Includes Demand Side Management tools such as time of use electricity rates, energy audits, efficiency incentives, and consumer education; also includes Demand Response tools such as utility controls, programmable devices, and two-way communication through advanced. metering infrastructure

including investor owned utilities, electric cooperatives and municipal utilities, regional transmission organizations (RTOs) as well as program implementation organizations (i.e., efficiency, utility and research and development agencies). The second category includes state-level regulatory authorities, researchers, environmental advocacy non-profits, and consumer advocacy non-profits (see Table 1 for stakeholder organization descriptions). The distinction between these two groups is based on whether or not the organization is involved in and responsible for daily operations of electricity systems; those in the "energy system operation experts" groups are directly involved, while organizations in the second category, "energy system actors" concentrate their efforts on more long-term policy, regulatory, and design aspects related to energy system planning. We conducted focus groups with analogous sets of stakeholder organizations in each of the three states.

In all cases, we collaborated with a contact person at the organization to identify and invite staff who engaged in electric grid innovations and smart grid efforts to participate in a focus group. Each focus group included at least two members of the research team serving as a facilitator and note-taker. The focus group facilitator asked the participants a broad suite of questions including their definitions of smart grid, opportunities and challenges of electricity system change in relation to smart grid, climate change and two questions focused specifically on Superstorm Sandy:

1. *How do you think Hurricane Sandy has changed awareness about energy systems?*
2. *How do you think Hurricane Sandy has changed awareness about climate change preparedness?*

Focus group participant answers to these two questions made up the majority of the data used for this analysis. It should be noted that definitions for awareness, climate change preparedness, climate change mitigation, and climate change adaptation were not provided to study participants so as to avoid biasing their responses to a particular perspective. This allowed participants to insert their own ideas and perceptions of these subjects into the focus group conversations. Analysis of text resulting from these discussions with energy system experts form the basis for this paper.

All focus groups were recorded and professionally transcribed. We coded the focus group transcripts with NVivo 10.0 software, which enabled us to explore the research question by identifing and characterizing discursive patterns and linkages between climate change and energy by analyzing text focused on both climate mitigation and climate adaptation (a priori categories). Details and examples of the coding scheme are included in Table 2. Our data analysis and interpretation were based on the principles of grounded theory [29], which offers an internally logical set of techniques for collecting and analyzing qualitative data. Following from this perspective, the statements made by our informants provided the basis for elaboration of our coding scheme, specifically for populating the subcategories within the climate mitigation and climate adaptation (Table 2). Because we sought to understand our informants' lived experiences associated with the electricity grid, it was important for these categories to emerge from and reflect the interactions that occurred during the focus groups. By following this approach, we were able to discover many of the ways that personal experiences and social contexts have shaped our informants' knowledge, beliefs, and attitudes related to electricity, energy, and the

socio-technical system it enables. We used a variety of techniques to manage issues of accuracy with the data, including triangulation, informant validation, clarification questions, and continual movement between data collection and analysis [30]. Concepts that emerged during this process enabled us to generate materials for training coders, thus enhancing intercoder reliability. We coded text focused on electrical grid reliability, resiliency, and system restoration as climate adaptation, and text focused on alternative energy strategies, emissions reductions, environmental benefits, demand-side management, and demand response as climate mitigation. Coding was completed by two independent coders who reconciled their coding results of each subcategory and achieved agreement represented by a 0.95 kappa coefficient or greater [31]. The coding framework was designed to determine the frequency of mitigation versus adaptation statements in the conversations as well as context regarding climate change and smart grid electricity changes.

4. Results

4.1. Comparisons across three different states

Our analyses show differences in the relative focus on climate adaptation versus climate mitigation among energy system stakeholders in the three states. This comparative analysis, though normative in its treatment of the three states, provides a snapshot during the dynamic year after a major energy system disruption. While other factors beyond the storm shape the different energy-planning conversations in the three states, the severely disruptive event – felt differently in all three states – allows for a detailed examination of how system planners are responding to new and unprecedented levels of risk linked to climate change in their professional lives.

Comparatively, we found the balance between conversations about adaptation versus mitigation was associated with the severity of the storm's impact in each state (Fig. 1). Among all the climate-related discourse that was coded in each focus group, Vermont conversations generally focused more heavily on climate mitigation (61%) than adaptation (39%), whereas Massachusetts conversations were more equally represented in post-Sandy discussions with 47% mentioning mitigation and 53% mentioning adaption, respectively. New York suffered the most storm damage of the three, and New York focus group conversations were dominated by discussion of climate adaptation (61%) with the remainder focused on mitigation (39%).

An interaction between two New York electricity operator employees demonstrates stakeholders concerns about how to respond to uncertainties of weather posed by climate change. As one respondent stated, “We don’t know the right thing to focus on [with] the very limited resources we do have.” In response, another participant made the comment, “to some extent it might be a distraction to talk about climate change. It may very well be a perfectly good idea to [have] a more resilient grid in the event that we have another Sandy next year.”

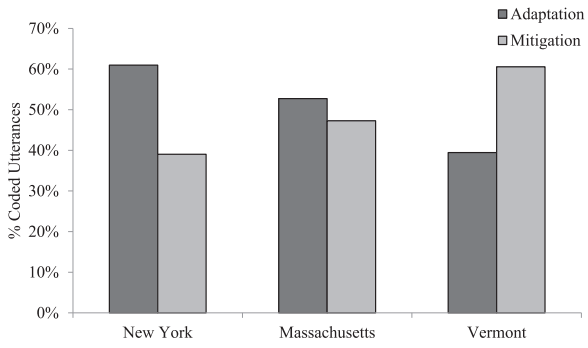

Fig. 1. State-level comparison of percent of coded utterances that focus on adaption versus mitigation.

The adaptation-leaning attitude toward climate change in post-Sandy New York is further epitomized by an employee of a New York investor-owned utility: “I think there is a general recognition that, okay, if this is global warming and these storms are going to become more frequent we need to be better prepared for it.”

Even though the storm was more severe in New York and Massachusetts, some Vermont participants also expressed concern about adaptation and this extended beyond the energy system. One Vermont consumer non-profit participant stated “Vermont is trying to rebuild infrastructure that actually would be somewhat resilient. Larger culverts that would actually be able to not wash out in another Irene. And the federal government is essentially saying, ‘No, we’re not interested in that. You just need to go find the culvert that washed out and put it back. That's like the level of preparedness that we’re interested in you having.’” More than a year before Superstorm Sandy, in August 2011, Vermont experienced extreme disruption from Hurricane Irene and the impacts of that storm remain salient and concerning for many Vermonters especially those involved in planning and investing in basic infrastructure [32].

As for the relationship between climate change and Superstorm Sandy, many but not all participants articulated or acknowledged an explicit connection. As one Vermont environmental non-profit participant put it, “almost everybody kind of associated Irene and Sandy with climate change.” A Massachusetts environmental non-profit respondent shared this perspective: “I think Sandy could be pointed to as a major factor in shifting the debate. Denial is no longer a valid concept. People might try it, but you can kind of laugh at it now.” Some study participants were less convinced and questioned the longevity of climate concerns after Sandy: “I’m a little skeptical about the persistence of how Sandy caused people to think about the resilience of infrastructure and our preparedness for climate change, in general” (MA consumer non-profit respondent). An employee of a Massachusetts investor-owned utility commented on the differentiation of policymaker and consumer perceptions on the links between climate change and Superstorm Sandy: “I don’t think anyone's making the connection [with climate change]…I think policymakers might, but our average customers just want it [the grid] to work and that's what they should expect.” One New York municipal utility participant highlighted increasing concerns about coastal vulnerability and the need for adaptation regardless of agreement about the cause: “Whether that conversation is going on or isn’t going, there is a real need to look at what is happening in the coastal area, in Long Island in particular, and in the broader sense because clearly we are getting weather. We are getting more difficult weather more frequently and we are getting changes to the levels of sea rise. So, I think those things have to be looked at.”

Within the adaption category, reliability and resiliency were of greater interest to energy system stakeholders than restoration of power. This was consistent across all three states (Fig. 2) and makes sense given how they interact with the system. Though smart grid was incorporated into these discussions, there was uncertainty and diversity of opinions related to how much smart grid would help manage shifting risks to the electricity system. As one respondent from a Massachusetts consumer non-profit stated, “When I think of the last 10 big power outages that we can think of, Hurricane Sandy being the most important point, I don’t think you could ever have a grid that was smart enough to solve that problem.” Another member of the same organization seconded this sentiment saying, “…the smart grid wouldn’t have stood up too well to Hurricane Sandy.” These statements highlight uncertainty that such sophisticated information systems could handle the issues presented during extreme weather events.

State-level focus on the mitigation subcategories were less consistent. For example, New York energy system stakeholders spent more time discussing demand-side management and demand response than the other two states (51% for New York compared to 43% and 37% for Massachusetts and Vermont). Though Massachusetts focus group participants also focused most heavily on demand-side management

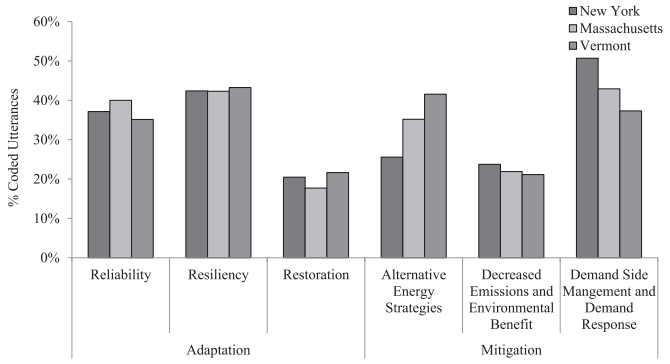

Fig. 2. State-level comparisons of adaption versus mitigation subcategories.

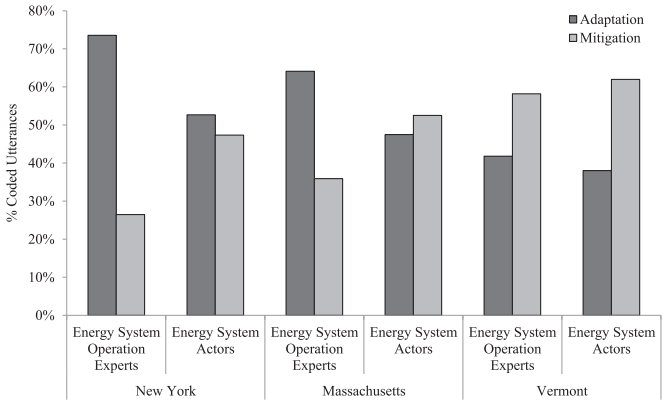

Fig. 3. State-level comparisons of adaption versus mitigation by energy system stakeholders.

and demand response, this was followed closely by alternative energy strategies (35%). Unlike New York and Massachusetts focus group participants, alternative energy strategies were the main focus of Vermont's stakeholder conversations about mitigation (42% of the discussion). In Vermont, where climate mitigation consistently received more attention than adaptation in post-Sandy conversations, one consumer non-profit participant called for "WWII style mobilization around climate over the next 10–30 years" insisting that current efforts are severely inadequate. The respondent went on to state that "Smart grid has to be part of that, otherwise we can't actually do what we need to do on climate [change]."

Among stakeholders in all states, the mitigation subcategory mentioned least frequently was decreasing emissions and benefits to the environment. Within the New York focus groups, however, the frequency of mentions of the subcategories for alternative energy strategies and decreasing emissions were almost the same (26% versus 24%). When decreased emissions and environmental benefits were mentioned, it was generally in relation to moving away from fossil fuels and toward renewable energy. According to one Massachusetts consumer non-profit respondent, "it would be ideal [if] something like the smart grid could just like maximize renewable energy use and clean energy use." This sentiment was shared by a Massachusetts municipal utility respondent: "I would think that the smart grid technology would allow us to manage that green business a little better within the community, and maybe offer us the ability to work more with companies that do more green development." Though smart grid was seen as part of climate mitigation strategies, it was limited, as one Massachusetts private utility participant stated, "smart grid is not going to fix the climate change problem."

4.2. Comparison among different stakeholders

In our analyses, we also examined differences between stakeholder groups, mainly energy system operation experts and energy system actors (Fig. 3). These analyses revealed some important contrasts among these different stakeholders. Most notable was the fact that energy system operation experts were more heavily skewed toward conversations of adaptation versus mitigation than were the other energy system actors (74% compared to 26% in New York State). As one New York private utility participant noted, "Within the past two months we've gone out and had regional meetings with the local government emergency management officials…I think there is a general recognition that, okay, if this is global warming and these storms are going to become more frequent, we need to be better prepared for it from that standpoint." Energy system actors (the organizations not involved in daily operation of the electricity system) in New York, however, were much more balanced with 53% of the discussion focused on adaption and 47% focused on mitigation. Massachusetts focus group participants showed the same tendency amongst their energy system operation experts, but energy system actors in the state were actually more focused on mitigation than adaptation (53% compared to 47%). According to a Massachusetts consumer non-profit participant, "I felt like the infrastructure is not in good condition for climate changing and we are ill prepared for climate change. Especially, New York is one place that has taken steps to address it. And so it's particularly disheartening to see the impact that the storm had on New York." Another member of the same organization acknowledged their worry about rebuilding the system using the same technology: "…by doing this we're putting these people in jeopardy, again. And that [would] be rebuilding in the same way that we did before, with the same infrastructure, we're putting more people in danger by bringing on climate change." Environmental non-profits in general (part of the energy system actors group), but even more noticeably in New York and Massachusetts, tended to use resilience rhetoric to speak to the urgency of climate change: "… this idea of more extreme weather…is this going to happen more often, are there things you are going to need to do to help the grids." Vermont served as the outlier with both the energy system operation experts and energy system actors focusing more of the discussion on mitigation (58% and 62% respectively) than adaption. The attitude of focus group participants in Vermont, a state that did not suffer to the same extent as New York and Massachusetts from Sandy but is no stranger to severe weather, remained more focused on mitigation compared to the other states. According to one Vermont utility, "We might make a political choice to control emissions that yeah, has a cost to us, but maybe we can learn that cost is a better cost than the cost of just having storms get worse and worse, and more devastating and harmful."

4.3. Variations in sense of urgency for system change

For some of the stakeholders who participated in our focus groups, Superstorm Sandy highlighted an urgency to respond to climate change. As stated by one New York regulator, "Climate change, climate change. Climate change – it's here," However, some participants doubted that this would change how the system was planned, as noted by a Massachusetts utility employee who thought that the average consumer was more interested in the short-term need of getting the power back on versus taking the opportunity to tackle the long-term issue of climate change mitigation and adaptation. But other utility employees saw the matter differently such as one New York participant who stated "I think there is a general recognition that, okay, if this is global warming and these storms are going to become more frequent, we need to be better prepared for it." Others also focused on this adaptation framework, like this comment from a Massachusetts regulator, "I think the main issue with Sandy is [it] has been on climate…How do we adapt? How do we become more resilient?" The same participant went on to state that "I think it definitely has had an effect, at least in providing politicians with cover."

Many focus group participants mentioned the limited time-frame after Superstorm Sandy during which climate change discourse was salient, and acknowledged that public attention is ephemeral and limited to a brief post-storm window. One Vermont private utility participant noted, "I think that the useful thing that Sandy, and Irene before it, have started to do, is to create a tremendous amount of anxiety." Vermont focus group participants from research institutions went a step farther, stating that "…it seems like people need a big catastrophe to remind them or just make them cognizant that they're kind of dependent on the energy systems" and that events like Superstorm Sandy serve as "a wake-up call of the vulnerabilities of the system." Other focus group participants also acknowledged that public attention is not durable. "I'm concerned that people just aren't going to be thinking about it six months from now" (MA consumer non-profit participant). Similar thoughts were shared by New York consumer non-profit respondents: "this neighborhood's pretty aware of the impact of Storm Sandy. At the same time, I think that the memory has faded, and the impact has faded significantly. My concern now is even something as tangible to New Yorkers as the actual experiences of [Super]storm Sandy, I think has very quickly faded." These comments demonstrate a worry about the limitations of focusing events to keep public attention on an issue long enough to shift public thinking and policy action on climate mitigation and adaption. A New York municipal utility participant may have summed it up best stating "I do not think that the political will is there enough to create a tipping point where there is actually action to solve a lot of those issues. You have a lot of climate change issues that impact Long Island, that impact the region, and the country as a whole, but if from the perspective of Long Island, I do not think there is enough political will yet that actually creates real and lasting changes."

5. Discussion

Climate change, extreme weather events and the adaptation of critical infrastructures affects cities and countries around the world. This research demonstrates the nuances of how a specific extreme event influences energy system stakeholders' perceptions about energy system planning and its connections with climate change. Our research adds to the literature on public perceptions of climate change and adaptation associated with extreme weather events (e.g., [40]) by looking directly at players within the energy sector that have direct influence over how climate change mitigation and adaption strategies are implemented. While we are unable to capture how the event changed the energy system stakeholder's thinking due to a lack of focus groups with participants before the event, focusing events like Superstorm Sandy provide important opportunities to explore different responses to the consequences of a changing climate and changing risks to energy systems. Although much of the initial policy discussions surrounding climate change focused on mitigation and how energy system planning could reduce greenhouse gas emissions [33], realization of the imminent need for climate adaptation strategies and planning has been growing as communities throughout the world face more frequent and extreme events that disrupt energy systems [24,34]. The insights from this paper can suggest future courses of action to promote energy system planning and adaptation efforts that respond both to perceived and actual needs to adapt and mitigate for a changing climate. Some possibilities would include allowing systems to be upgraded with more resilience and reliable technology after an extreme event instead of requiring replacement with the previous infrastructure as noted by multiple participants from the various states. This would require for *a priori* changes in existing policies and regulations by politicians and regulators.

In our study, we found that the more directly impacted a state was by Superstorm Sandy, the greater the focus among energy system stakeholders on climate adaptation compared to climate mitigation. We also found that energy system operation experts in New York and Massachusetts were much more focused on adaptation compared to the other energy system actors in those same states, who expressed more balance between mitigation and adaption. We recognize that other factors besides Superstorm Sandy may also contribute to these differences, but these results demonstrate a divergence of perspectives on how to move forward in different states and among different stakeholder groups in the wake of a focusing event (i.e., whether to focus more effort on climate adaption versus climate mitigation, or vice versa). Vermont stakeholders consistently had a greater focus on mitigation than adaptation; this was clear among both energy system operation experts and the other energy system actors.

Initial conditions aside, these results raise several critical questions for energy systems worldwide: Are energy system planners only able to garner sufficient political support to change energy systems after a high degree of destruction? Or, can we incorporate the risks from climate change to create sustainable energy systems without devastating shocks to the system? Furthermore, can we devise a strategy that would allow for these devastating events to be used as an opportunity to upgrade a seemingly failing system instead of rebuilding the former system? How can energy system planners more effectively integrate short-term responses to specific disruptive events with longer-term system-wide transformation? These questions relate to a series of tensions that are increasingly emerging among energy system decisions-makers related to the balance between incremental versus more transformative radical change [8].

These results speak to important considerations for electricity system and critical infrastructure planning around the globe. First, climate adaptation is becoming a larger part of planning because of the growing threat of events like Superstorm Sandy. Societal actors in the energy sector, but also in other sectors including health, are attempting to address their disaster preparedness through discussions of alternative energy sources, grid reliability, and microgrid system implementation for disaster response, but often do so in isolation [35,36]. Residents and energy system experts alike are worried about climate-related sea level rise, coastal flooding, and storm surge from future extreme events post-Superstorm Sandy [37]. Even though discussions of Superstorm Sandy have waned over time [38], an inevitability of future catastrophic events expressed by focus group participants, the storm seems to be having a lasting effect as one of a series of weather-related focusing events that have sensitized the American public to climate risk and steered toward a focus on *climate change preparedness*. Focus group participants often talked about preparedness in relation to resiliency and readiness to face future weather events, but this concept has the ability to be more inclusive. Climate change preparedness is a relatively new phrase in climate discourse that includes both climate mitigation *and* adaptation and testing these hypotheses across international settings could be a fruitful extension of this research [39,40]. By uniting climate change mitigation and adaptation under the banner of climate change preparedness, the strategies are presented as no longer being at odds, but as part of the same goal. We recognize that energy systems will face a diversity of risks from climate change, but how these risks will be integrated into energy system and critical infrastructure planning depends on how societal actors perceive and frame events like Sandy.

Second, the differences that emerged in our results between the energy system operation experts and the other energy system actors highlight the roles they play in operating and planning the energy system and the different frames from which they engage and envision the future. Energy system operation experts are at the front lines of keeping the power on, and while utility personnel are also responsible for long-term system planning, their framing reflects their institutional mission of providing continued reliable and affordable electric service for customers, regardless of the weather. This more near-term time-frame must incorporate maintaining daily energy system reliability and operations with the legacy infrastructure. Other energy system actors, on the other hand, have the luxury of envisioning future energy systems unencumbered by daily operational

logistics. Perhaps this perspective allows these actors a greater capacity to think in a long-term time-frame in which more elusive and perhaps radical changes might be envisioned, planned, developed and deployed.

After a disaster, electricity system operation experts are responsible for restoring electricity to customers as quickly as possible. This priority was noted by several of our study participants. In 21st century North America, people suffer and social systems grind to a halt when they are not powered by electricity. Longer-term system planning efforts which incorporate emerging climate risks, however, require a time horizon which stretches decades and requires a level of political commitment and trillions of dollars of private and public investment which has often been difficult to secure. This has been difficult to do in the United States, where energy system planning is fragmented across multiple jurisdictions and subject to shifting political priorities and market forces. When U.S. Department of Energy Secretary Ernie Moniz spoke after Superstorm Sandy of "rebuilding in a smart way," (Moniz 2013), he underlined a critical tension between restoring power in the short-term and the need for creating a future system which is both reliable to system perturbations and resilient in the face of new risks. Even though Sandy caused massive system damages, because the needs to restore power were so urgent, and system planning very slow, it was difficult for electric utilities to use these disruptions as opportunities to upgrade and integrate new technologies immediately. This, however, has not ruled out operator concerns about future extreme events from climate change. In fact, such concerns are leading to research that is evaluating the risks to energy system infrastructures from more extreme weather events [41]. How future energy system plans integrate perceived risks and opportunities of climate adaptation and climate mitigation will be critical in shaping energy system change and expanding this study to other locations would allow for fruitful comparison of how the risks and opportunities are framed.

6. Conclusions

Superstorm Sandy served as a dramatic focusing event raising societal consciousness surrounding the multiple connections between climate change and the electricity system. Energy and critical infrastructure systems around the world face new and emerging threats. Throughout the past decade, climate change and energy have been commonly linked in public discourse through the mitigation lens, often focusing on how reductions of carbon emissions from energy systems could reduce the growing climate change threat. As these climate change fueled threats become imminent and less distant, linkages between climate and energy are also integrating climate adaptation and the need to enhance resilience of energy systems to reduce critical infrastructure vulnerability to inevitable climate impacts. This research contributes to understanding this transition in thinking by exploring the mitigation and adaptation balance among stakeholders after one particularly disruptive climate-related event.

When Superstorm Sandy knocked out power for over 10 million people, modern infrastructure ground to a halt in a large part of the United States. Energy systems must simultaneously adapt to a changing climate and mitigate future emissions. Therefore, how experts involved in energy system planning are framing these intertwined responses is critical for shaping, planning and developing future energy systems. Events like Superstorm Sandy provide an opportunity to explore how different actors across different contexts respond to the consequences of a changing climate and changing risks to energy systems. This analysis provides insights on the complexities that different stakeholders within different institutional contexts are negotiating when balancing climate adaptation and climate mitigation in electricity system planning and smart grid development. The results reveal diversity in how different stakeholders focus more or less on mitigation versus adaptation, with adaptation featuring more prominently among those recently impacted by a severe disruptive event [25,33,34,40].

This analysis also highlights the adage; "where you sit is where you stand: " i.e. local context or professional orientation shapes the lens through which people perceive issues, risks and opportunities. How to respond to connect climate change and energy system change, whether to focus more on mitigation or adaptation, depends on where you are located and multiple factors that contribute to perceptions of risks and benefits in those places.

A compelling conclusion of this research relates to the prioritization of adaptation measures among those who have been recently and directly impacted by a severe event and among those who are directly involved and responsible for day-to-day operation of the electricity system. This suggests that investments and planning for climate adaptation may continue to grow perhaps beyond climate mitigation, because often adaptation and mitigation are framed as competing priorities rather than intertwined goals [25]. Given limited resources for electricity system change, these results highlight the value of considering synergistic investments that might simultaneously contribute to mitigation and adaptation.

As climate change related disruptions of all kinds become more common—from both extreme weather events as well as longer term system changes like droughts, sea-level rise and shifts in precipitation, this analysis confirms that adaptation becomes more important, if not a priority, for system stakeholders. Advocates interested in creating sustainable energy systems would do well to define synergistic system improvements which address both adaptation and mitigation drivers instead of competing strategies vying for the same resources. While adaptation may be politically easier in North America, the global discussions highlight the importance of mitigation in the electricity sector remaining a critical component of addressing climate change [42]. Therefore, efforts to promote energy system change should work to ensuring mitigation and adaptation efforts are linked, possibly through a framing like climate preparedness. However, it is also important to remember that decisions supporting system protection versus long-term change of energy resource mixes take place in different decision venues and are dominated by different priorities and interests.

Finally, this research highlights the dynamic and evolving nature of societal responses to climate change and suggests that the notion of climate preparedness, which integrates both climate mitigation and climate adaptation, is a useful frame to consider the dynamic and complex factors shaping societal responses to climate change. Climate preparedness offers a valuable framing, especially considering that communities, states, and countries are faced with the simultaneous challenges of both minimizing risks of already occurring climate impacts through adaptation, and minimizing long-term risks to humanity through mitigation [40]. While consideration of climate change policy has historically focused on climate change mitigation efforts [33], recognition of the growing need to support adaptation is becoming a mainstream priority [25,34]. Preparedness provides a frame that incorporates a combined mitigation/adaptation strategy which could reduce competition between these two distinct societal approaches to responding to the risks of climate change.

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